

CHEMISTRY EXTENDED ESSAY

“Determining the buffer capacity of lakes and ponds that resist the quick pH change and necessary for water living organisms.”

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ABSTRACT

pH level is a very important factor on water living organisms. For example, acidic water affects the functionary of fish gills; inhibit their growth and passion fish eggs. Acid rain is one of the major factors that affect the pH of lakes, rivers and ponds. However minor changes happen in nature all the time and nature has its own way to cope with such problems. Some lakes can protect themselves from acid rain with their natural buffer systems. For this reason, I decided to work on buffer systems of fresh water resources such as lakes and ponds. I collected water samples from lakes, ponds and rivers in Turkey. I measured pH values of these samples before and after adding small amounts of acid with different concentrations to determine the resistance of them to pH changes.

By referring my results the buffer capacity depends on one important factor: Acid rains. The lakes and ponds in Turkey get different amount of rain per year. This affects their buffer capacity and when their buffer capacity damaged the organisms living on it become extinct. To sum up my aim in this essay is to find the buffer capacities of lakes and ponds in Turkey. Keywords: Buffer systems, pH resistance, Buffer capacity.

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1. INTRODUCTION

Buffer systems are mediums where there is a weak acid and its conjugate base (or a weak base and its conjugate acid) present in solution. This solution provides a resistance to the immediate change in the solution's pH. (Consider the weak acid HF and its conjugate base F^- : $HF + H_2O \rightleftharpoons H_3O^+ + F^-$) When strong acid is added, it is neutralized by the conjugate base. ($F^- + H^+ \rightarrow HF$) When strong base is added, it is neutralized by the weak acid. ($HF + OH^- \rightarrow H_2O + F^-$) However, too much acid or base will exceed the buffer's capacity, resulting in significant pH changes.

The bicarbonate buffering system is an important buffer system in the acid-base homeostasis of living things, including humans. As a buffer, it tends to maintain a relatively constant plasma pH and counteract any force that would alter it.

To conclude pH levels have an important role in aqua fauna. A little change in pH may cause death of millions of creatures immediately. That's why, buffer systems have an extremely important effect on the living organisms, they help the sustainability of stable pH levels. With the presence of a buffer systems, the water environment is likely to keep its acidity constant, in spite of natural outer effects. However, with the growing threat of acid rains, it is important to determine the consequences and the role of buffer systems in it.

2. RESEARCH QUESTION

Is there any difference between the buffer systems in different lakes and ponds in terms of their resistance to immediate pH changes caused by acid rains stimulated by adding small amount of HNO_3 (Nitric Acid) of different molarities where pH measured by vernier pH sensor?

3. BACKGROUND INFORMATION

3.1 What Is A Buffer Solution?

Buffer solutions are aqueous solutions that are resistant against changes in pH level, which are caused by outer effects. In order to fully comprehend this subject, it is important to understand the concepts of acidity, alkali and pH.

3.2 What Is Acidic and What Is Basic?

Acidity can be simply defined as the H^+ ion concentration in a solution. In order to classify substances according to this concept, a measurement called pH level is present and substances are classified as basic, neutral or acidic accordingly. pH measures the concentration of H^+ ions in a solution by using the following equation.

$$\text{pH} = -\log [\text{H}^+]$$

It is possible to observe that, pH value is growing when H^+ concentration is decreasing or visa versa. The negative correlation between pH value and H^+ concentration may cause misunderstanding and confusion. This relation causes the higher H^+ concentrations to have smaller values. So, while acidic compounds vary in smaller values of pH and bases' are in bigger, as shown on *Figure 1*.

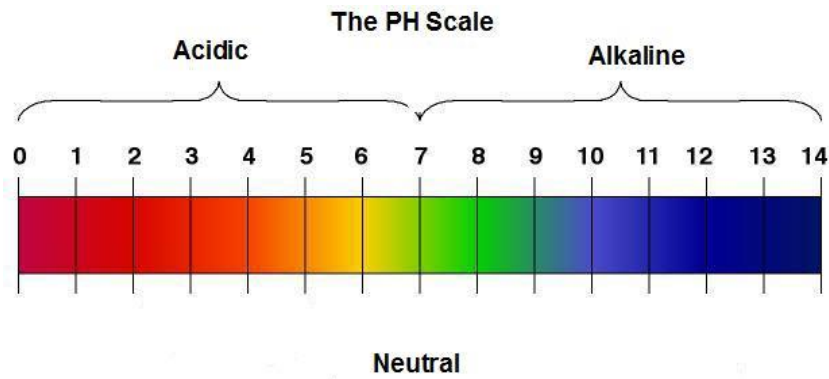


Figure I: Representation of scales of acidity and alkalinity on pH levels.¹

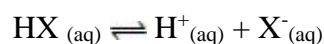
If a substance has a H^+ concentration greater than 10^{-7} or in other words, pH value smaller than 7, it is called acidic. If the pH level of it is equal to 7, it is called neutral and if it's pH level is bigger than 7, then it is called basic. The closeness of pH value of a substance to 7, determines its strength. A strong acid or base has a distant pH value from 7, such as 1 or 14. Acidic and basic substances are able to react with each other and form the end products called salts. The characteristic of a salt is determined by the strength of the reactants. The acidity of a salt is similar to the stronger reactant. For example, reaction of a strong acid with a weak base produces an acidic salt and visa versa.

Addition of even small amounts of strong acids or bases can change the pH level of a solution in a very big scale. However, buffer solutions are able to compensate such effect of acidic or basic substances to a specific amount.

¹ <http://strengthnutrition101.blogspot.com/2012/03/science-behind-ph-and-performance-part.html>

3.3 Properties of Buffer Solutions

In order to fully comprehend how this effect works, let's consider the following equation.



Where HX is a solution and X is an element formed from HX

There are two possible additions that can majorly effect the pH, a strong acid or a strong base. If a strong acid is added, the equilibrium would shift to left and some of ionised HX would form the compound again. If a strong base is added, the OH^{-} ions of the base would combine with H^{+} in the solution and form water. The shift of equilibrium to right would form more H^{+} ions, which would replace the ones that formed water. So, in either case, by reacting with the additional compound, the buffer solution shifts the equilibrium to required direction and stabilize the pH level.²

The buffer effect is available for a solution, only if it includes a weak acid or weak base compound and a salt derived from it. In order to observe such effect, the concentration of these compounds should be greater than the concentration of strong acid or base, which is externally affecting the pH level. That's why, a weak acid or base alone, is not enough to obtain a buffer, as it would not be solved enough.

The key point of buffer solutions is that, they contain both acidic and basic species, that can react with both acidic and basic substances that are added from outside. As these substances include similar matters and salts are produced from weak soluble, they do not react with each other and can have either acidic or basic characteristic when an outer effect is present. So, both types of buffer solutions can compensate the effect of acids and bases by reacting them with their weak substance or their salt, according to the added soluble.

² Green, John & Damji, Sadru: International Baccalaureate, Chemistry 3rd Edition, IBID Press, 2008 (pg. 221-222)

3.4 Acid Rains

Acid rains are very important for the pH balance of lakes and ponds. The most common outer effect to change pH is the acid rains. In this experiment, such outer effect would be simulated by adding HNO_3 (with different molarities) to gathered lake water samples.

National Geographic defines acid rain as, “*Acid rain describes any form of precipitation with high levels of nitric and sulfuric acids.*”³The most important aspect of these rains is their low pH levels. While ordinary rainwater has the slightly acidic pH level of 5.6, acid rain’s may be much less. Because of the consumption of fossil fuels, gases like SO_2 and NO_x are released, these substances react with water and form diluted solutions of nitric and sulfuric acids, these formations lower the pH level of rainwater. Acid rain causes the addition of a big amount of acidic liquid into the water of lakes. In this case, the pH level could be rapidly changing according to the weather. Water creatures have low tolerance for pH changes and they need an environment with stable acidity, in this case the effectiveness of buffer solutions may determine the living in of a lake.

³ <http://environment.nationalgeographic.com/environment/global-warming/acid-rain-overview/>

4. METHOD

The aim of this experiment is to compare the buffer capacity of water samples from different lakes of Turkey, which have different pH levels. Our criteria is the resistance of water to pH changes against the added HNO_3 solution. Measuring pH values before and after the acid is added and calculating percentage change in pH shows buffer capacities of these lakes. (Also there are some other methods such as measuring with yellow indigo or pH paper but the reason of choosing this method is it gives most accurate results

4.1 Variables

Dependent Variable: Percentage changes in pH of water samples after addition of small amount of HNO_3 of different molarities.

Independent Variable: Amount of added nitric acid to water samples. (chosen to be 0.05M, 0.1M, 0.2M, 0.5M and 1.0M)

Controlled Variables:

- Temperature of medium :Temperature of water samples stabilized with water bath to keep the temperature constant at about $30\text{-}32^\circ\text{C}$
- Room Pressure (accepted as 1067 Pa)(Measured by barometer and stabilized by making the experiment in the same place)
- Humidity: all trials of experiment is done in the same room under same conditions and no air ventilation
- Type of acid solution added (HNO_3)
- Number of drops of HNO_3 added to water samples

The changes in environment may effect chemical properties of the substances that we use, like their solubility or concentration. That's why, all trials of experiment is done in the same room under same conditions and no air ventilation. So, variables like humidity, pressure and temperature could be stabilized.

4.2 Materials

- 1.0M HNO₃ solution (x5)(100 ml)
- 0.5M HNO₃ solution (x5) (100 ml)
- 0.2M HNO₃ (x5) (100 ml)
- 0.1M HNO₃ (x5)(100 ml)
- 0.05M HNO₃ solution (x5)(100 ml)
- pH sensor (Vernier)
- Sample water gathered from lakes and ponds in Turkey; (x8)
- Menderes,
- Kale,
- Pamukkale,
- Temeli,
- Afyon,
- Denizli Tavas,
- Denizli Acıgöl,
- Kale/Akçay.
- Beaker (500.0 (± 0.1) mL)
- A thermometer (± 0.5°)
- Measuring cylinder (10cm³) (x2)
- Measuring cylinder (200cm³) (x2)
- Water bath
- Clamp stand (x2)
- Clamps (x2)

4.3 Procedure

1. The windows and doors of the laboratory were closed at all times during the experiment to keep the temperature and air pressure stable.
2. The water samples were separated to different beakers to be used in different trials. In each trial 20 ml of sample of water was used.
3. 20 ml of each water sample were placed in 100 ml of beakers.
4. The initial pH value of samples were measured by using a Vernier Sensor
5. Then 10 drops of 1.0M HNO_3 solution is added to each beaker mixed and pH values were measured by Vernier pH sensor and recorded to data table.
6. Steps 2.3 and 4 were repeated 4 more times
7. Same procedures was followed for 0.5M , 0.2M , 0.1M and 0.05M HNO_3 solutions.

4.4 Safety Information & Precautions

Acids are known to be very corrosive substances, even though they might be in small molarities. Especially strong acids like HNO_3 can be very dangerous for health, in a direct contact. That's why, During all parts of the experiment involving HNO_3 safety goggles and surgical gloves are worn. Water samples may contain microorganisms. Avoid physical contact with them to prevent any danger of infection and use safety clothing.

5. DATA COLLECTING

All of the experiments are completed in the Chemistry Laboratories of TED Ankara College Foundation High School. Water samples are gathered from the lakes, which was arranged by myself.

	Trail 1		Trail 2		Trail 3		Trail 4		Trail 5	
Samples	Initial (± 0.01)	1M (± 0.01)	Initial (± 0.01)	1M (± 0.01)	Initial (± 0.01)	1M (± 0.01)	Initial (± 0.01)	1M (± 0.01)	Initial (± 0.01)	1M (± 0.01)
Menderes	6.79	1.37	7.53	1.32	6.73	1.88	6.65	1.73	6.82	1.37
Kale	7.69	2.36	7.68	2.36	7.72	1.70	7.75	1.80	7.65	1.52
Pamukkale	7.78	1.46	7.86	1.46	7.80	1.76	7.79	1.75	7.77	1.94
Temeli	7.54	1.51	7.58	1.51	7.52	1.68	7.72	1.49	7.53	1.57
Afyon	7.95	1.41	6.64	1.41	7.90	1.72	7.82	1.52	7.92	1.24
Denizli Tavas	7.63	1.53	6.38	1.53	7.50	1.28	7.60	1.90	8.22	1.67
Denizli Acıgöl	6.65	1.65	6.87	1.65	8.00	1.63	8.02	1.20	8.80	1.44
Kale Akçay	8.16	1.34	6.55	1.34	8.15	1.70	8.17	1.28	7.74	1.31

Table 1: Initial and final pH values of addition of 1M HNO_3 of water samples.

	Trail 1		Trail 2		Trail 3		Trail 4		Trail 5	
Samples	Initial (± 0.01)	0.5M (± 0.01)	Initial (± 0.01)	0.5M (± 0.01)	Initial (± 0.01)	0.5M (± 0.01)	Initial (± 0.01)	0.5M (± 0.01)	Initial (± 0.01)	0.5M (± 0.01)
Menderes	6.49	1.82	7.53	1.82	6.73	1.88	6.65	1.73	6.82	2.37
Kale	7.65	1.74	7.79	1.77	7.72	1.70	7.75	1.80	7.96	1.92
Pamukkale	7.78	1.62	7.76	1.63	7.80	1.76	7.79	1.75	7.77	2.94
Temeli	7.54	1.45	7.59	1.49	7.52	1.68	7.72	1.49	7.53	1.57
Afyon	7.95	1.64	6.64	1.64	7.90	1.72	7.82	1.52	7.92	1.34
Denizli Tavas	7.66	1.23	6.38	1.22	7.50	1.28	7.64	1.09	8.22	2.67
Denizli Acıgöl	6.65	1.58	6.87	1.58	8.07	1.63	8.09	1.02	8.80	2.44
Kale Akçay	8.19	1.25	6.55	1.25	8.15	1.70	8.17	1.28	7.74	2.91

Table 2: Initial and final pH values of addition of 0.5M HNO_3 of water samples.

	Trail 1		Trail 2		Trail 3		Trail 4		Trail 5	
Samples	Initial (± 0.01)	0.2M (± 0.01)	Initial (± 0.01)	0.2M (± 0.01)	Initial (± 0.01)	0.2M (± 0.01)	Initial (± 0.01)	0.21M (± 0.01)	Initial (± 0.01)	0.2M (± 0.01)
Menderes	6.41	1.37	7.53	1.82	6.73	1.59	6.65	1.73	6.82	2.76
Kale	7.98	2.36	7.79	1.77	7.72	1.70	7.84	1.80	7.96	1.92
Pamukkale	7.78	1.46	7.93	1.63	7.80	1.76	7.79	1.75	7.71	2.54
Temeli	7.54	1.51	7.59	1.49	7.52	1.68	7.72	1.49	7.53	1.57
Afyon	7.95	1.41	6.64	1.64	7.90	1.72	7.82	1.52	7.92	1.77
Denizli Tavas	7.66	1.53	6.32	1.22	7.50	1.79	7.64	1.99	8.22	2.67
Denizli Acıgöl	6.65	1.65	6.87	1.58	8.47	1.63	8.09	1.32	8.83	2.44
Kale Akçay	8.19	1.34	6.59	1.25	8.15	1.75	8.17	1.28	7.74	2.81

Table 3: Initial and final pH values of addition of 0.2M HNO_3 of water samples.

	Trail 1		Trail 2		Trail 3		Trail 4		Trail 5	
Samples	Initial (± 0.01)	0.1M (± 0.01)	Initial (± 0.01)	0.1M (± 0.01)	Initial (± 0.01)	0.1M (± 0.01)	Initial (± 0.01)	0.1M (± 0.01)	Initial (± 0.01)	0.1M (± 0.01)
Menderes	6.47	1.33	7.53	1.82	6.73	1.59	6.65	1.73	6.82	2.76
Kale	7.95	2.32	7.79	1.77	7.72	1.77	7.84	1.85	7.96	1.92
Pamukkale	7.70	1.41	7.97	1.63	7.88	1.76	7.79	1.75	7.71	2.54
Temeli	7.54	1.51	7.59	1.49	7.52	1.68	7.72	1.49	7.53	1.57
Afyon	7.95	1.41	6.64	1.66	7.90	1.72	7.82	1.52	7.92	1.79
Denizli Tavas	7.63	1.51	6.32	1.22	7.05	1.79	7.64	1.09	8.22	2.67
Denizli Acıgöl	6.65	1.65	6.87	1.58	8.07	1.63	8.09	1.02	8.83	2.44
Kale Akçay	8.19	1.39	6.59	1.25	8.17	1.75	8.15	1.28	7.74	2.81

Table 4: Initial and final pH values of addition of 0.1M HNO_3 of water samples.

	Trail 1		Trail 2		Trail 3		Trail 4		Trail 5	
Samples	Initial (± 0.01)	0.05M (± 0.01)	Initial (± 0.01)	0.05M (± 0.01)	Initial (± 0.01)	0.05M (± 0.01)	Initial (± 0.01)	0.05M (± 0.01)	Initial (± 0.01)	0.05M (± 0.01)
Menderes	6.77	1.33	7.52	1.82	6.73	1.59	6.65	1.63	6.82	2.76
Kale	7.93	2.32	7.79	1.77	7.72	1.73	7.84	1.85	7.96	1.92
Pamukkale	7.76	1.31	7.97	1.63	7.88	1.76	7.79	1.75	7.71	2.56
Temeli	7.54	1.51	7.53	1.49	7.52	1.68	7.72	1.49	7.53	1.57
Afyon	7.20	1.41	6.64	1.66	7.92	1.72	7.82	1.52	7.92	1.79
Denizli Tavas	7.63	1.51	6.32	1.22	7.50	1.79	7.64	1.09	8.22	2.67
Denizli Acıgöl	6.65	1.65	6.87	1.58	8.07	1.66	8.09	1.02	8.83	2.44
Kale Akçay	8.12	1.39	6.59	1.25	8.17	1.75	8.15	1.28	7.76	2.81

Table 5: Initial and final pH values of addition of 0.05M HNO_3 of water samples.

6. DATA PROCESSING

6.1 Calculations

In order to have more understandable and comparable results, the change in pH is converted to percentage rate. Then, the rates are compared and the powers of buffer effect of water samples are analyzed. An example of the method to convert the change to percentage is given below.

Example calculation for the five trials of water sample(in a HNO_3 solution) from Menderes:

Trail 1

1M: Before adding HNO_3 : 6.79

1M: After adding HNO_3 : 1.37

$$\frac{6.79 - 1.37}{6.79} \times 100 = 79.8 \%$$

Trail 2

1M: Before adding HNO_3 : 7.53

1M: After adding HNO_3 : 1.32

$$\frac{7.53 - 1.32}{7.53} \times 100 = 82.5 \%$$

Trail 3

1M: Before adding HNO_3 : 6.73

1M: After adding HNO_3 : 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 72.1 \%$$

Trail 4

1M: Before adding HNO_3 : 6.65

1M: After adding HNO_3 : 1.73

$$\frac{6.65 - 1.73}{6.65} \times 100 = 74.8 \%$$

Trail 5

1M: Before adding HNO_3 : 6.82

1M: After adding HNO_3 : 1.37

$$\frac{6.82 - 1.37}{6.82} \times 100 = 79.8 \%$$

Then I take the average values of these calculations:

$$\frac{79.8 + 82.5 + 72.1 + 74.8 + 79.8}{5} = 77.7 \%$$

By doing the same calculations to means of all water samples, data on Table VII are obtained.

Samples	1.00 M	0.50 M	0.20 M	0.10 M	0.05 M
Menderes	77.7± 0.58	82.5±0.30	72.1±0.22	74.8±0.47	79.8±0.21
Kale	82.5±0.76	79.6±0.31	76.0±0.65	73.9±0.32	72.6±0.45
Pamukkale	84.9±0.58	81.9±0.44	73.5±0.47	73.6±0.43	71.6±0.87
Temeli	79.5±0.49	75.5±0.56	71.3±0.45	68.1±0.28	61.2±0.23
Afyon	77.3±0.59	73.5±0.12	67.8±0.94	61.4±0.36	53.5±0.65
Denizli Tavas	76.6±0.77	75.3±0.38	69.1±0.86	61.3±0.33	59.2±0.77
Denizli Acıgöl	71.4±0.87	62.9±0.35	59.4±0.67	55.3±0.21	52.3±0.56
Kale/Akçay	78.3±0.40	69.2±0.65	65.3±0.66	63.5±0.16	63.5±0.43

Table VII: The percentage of changes in pH levels are shown above

6.2 Theoretical Values

Since the experiment wasn't made by someone I assume Theoretical Values as average values.

For Menderes River

For 1M HNO₃ solution : 77.7± 0.58

For 0.5M HNO₃ solution : 82.5±0.30

For 0.2M HNO₃ solution : 72.1±0.22

For 0.1M HNO₃ solution: 74.8±0.47

For 0.05M HNO₃ solution: 79.8±0.21

6.3 Uncertainty Calculations

From Menderes 1M HNO₃

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Menderes river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Menderes river is = 77.7 ± 0.58
Error Calculations

6.4 Error Calculations

For 1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

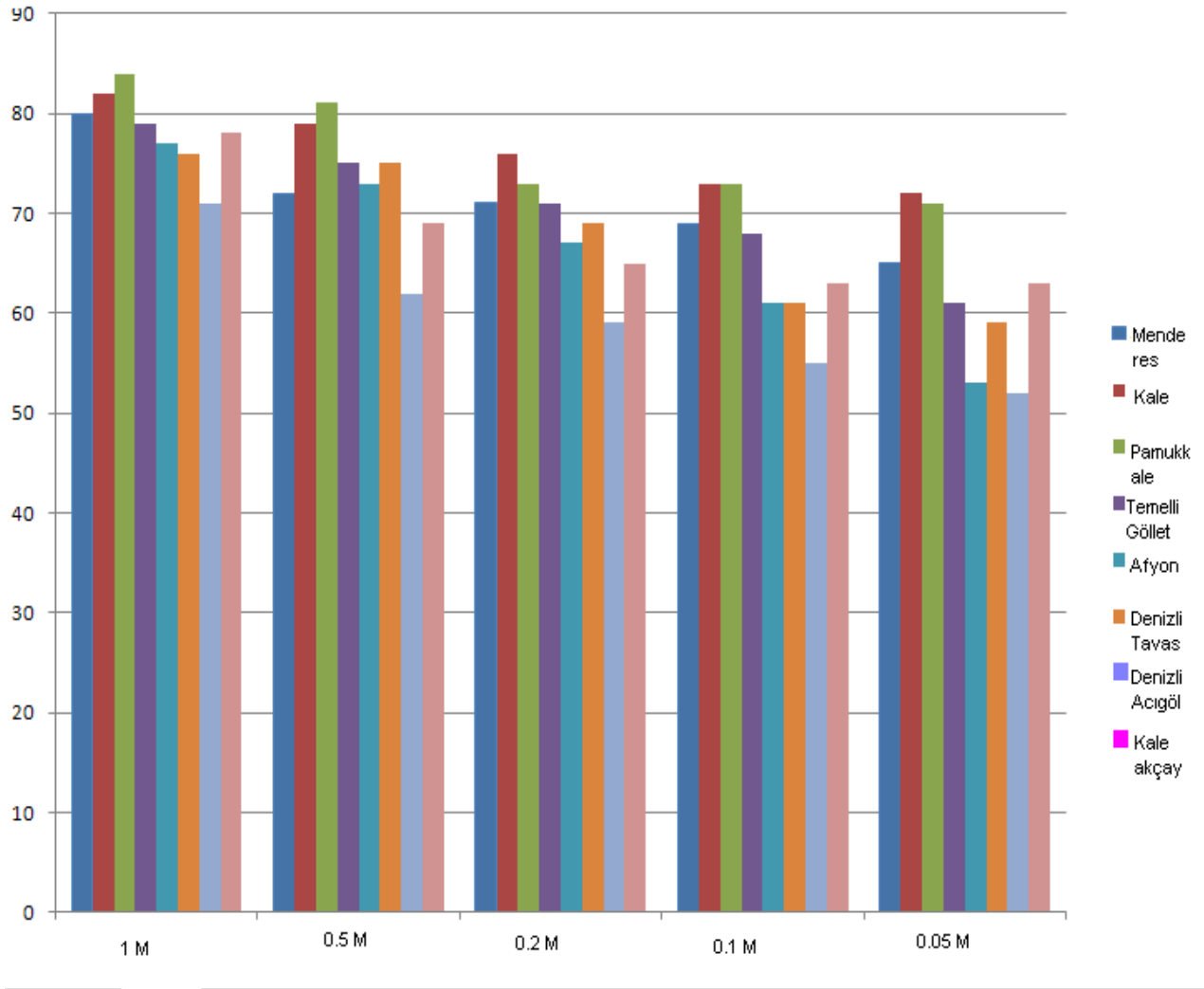
Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

6.5 Interpretation of Results



Graph I: Bar graph of the percentage of pH change

Table VII (Page 13) gives the final results that can be compared and analyzed. By using this data, the research question and hypothesis will be examined and by visualizing these results on Graph I, it becomes easier to observe the differences between treatments.

As seen on the bar graph, the buffer effect of treatments differs for different molarities of added HNO_3 . However, the smallest pH change is in Denizli Acıgöl water sample for all treatments. The largest change is in either Kale or Pamukkale. So, the most effective buffer solution is present in Denizli Acıgöl and the least effective ones are Kale and Pamukkale.

The lake which has the most buffer capacity : Denizli Acıgöl

The lake which has least buffer capacity: Kale Akçay and Pamukkale

7. CONCLUSION & EVALUATION

As a mentioned in Appendix my aim is to find the buffer capacities of the lakes in Turkey. By making several calculations I found that the buffer capacities of the rivers in Turkey aren't same. (Bar graph) Shows that there is a significant difference in buffer capacities of the lakes in Turkey.

First of all, the controlled variables are kept stable and they were measured frequently to make sure they are really constant. However, preventing air circulation and any heating may not be as efficient as a controlling method as we thought. For more precise results, using an isolated, computer controlled room would make the experiment more scientific.

Secondly, the experimentation process may be optimized. The measurement tools were sensitive, with very low, almost negligible, uncertainty rates. The materials, on the other hand, were prepared by the lab assistants and me, the whole pre-experiment process was controlled and measured by two observers, one of them was professional. The solutions or tools like beakers and flasks, does not seem like to be the cause of this precision loss. The biggest possibility would be human error. Data processing and calculations were done carefully and checked repeatedly by me, with the assistance of my supervisor. In this case, the only logical explanation would be the human error during the experiment. The measurements may be wrong. For example, addition of 25 mL instead of 20mL can cause crucial deflections.

However, the most important reason of such large errors may not be related to the experimentation, but only to the way we evaluate it. This experiment is based on a study held on particular examples, without any reference or generalisation. So, as theoretical value was derived from the data that are obtained from experiment, as well. This method is the best way to guess the theoretical value, but it is not really scientific to compare results of an experiment with a reference that is calculated from the same experiment.

During this experiment, the relation between the living conditions and buffer solutions were investigated. As a result of comparisons, it is observed that the most effective buffer solution belongs to Denizli Acıgöl (page 16), which is the lake with the second biggest water creature population. The biggest population is in Pamukkale, which is because of some neglected aspects like mineral density, reproduction of creatures, etc. So, a more stabilized pH level is possible only if effective buffer solutions are present and this presence create more liveable environments for water creatures. In our case, Denizli Acıgöl has one of the largest populations and with the least change in pH during experiment, has proven our hypothesis.

The effect of acid rains on buffer solutions are analyzed with reference to the geographical properties of Turkey. The acid rains disturb the equilibrium of buffer agents in solutions. So, the lake that takes the least rain would have the strongest buffer effect, assuming all rains include same amount of acidic substances. In Turkey's land, generally the easter parts get less rain, so the buffer solutions of lakes from the easter parts of Turkey were expected to be bufferwise more powerful. This expectation was fulfilled.

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APPENDIX I

In this part I will briefly introduce the lakes that I took samples.

Menderes River

- It's one of the biggest river in Turkey
- Its length is 548 km.
- Its average rain per year is 543mm.
- Its one of the most suitable river for agriculture.
- In recent years because of factory wastes and the wrong usage of fertilizer the river became dirty.
- The river ecosystem is being in danger of extinct.



The photo of the Menderes River

Kale River

- Its total length is 245 km.
- Its average rain per year is 324 mm.
- Because of the dirtiness of water and its physical properties a very few range of species live in this river



The photo of Kale River

Pamukkale

- It is 2,700 meters (8,860 ft) long, 600 m (1,970 ft) wide and 160 m (525 ft) high. It can be seen
- from the hills on the opposite side of the valley in the town of Denizli, 20 km away.
- Tourism is and has been a major industry.
- In this area, there are 17 hot water springs in which the temperature ranges from 35 °C (95 °F) to 100 °C (212 °F).



The photo of Pamukkale

Temelli Gölleti

- It is very small lake in the capital city of Turkey ; Ankara.
- It gets 100mm rain per year.
- Its total length is 2km.



The photo of Temelli Gölleti

Afyon

- It gets 250 mm rain per year
- Its total length is 142 km.
- Because of the ratio of rain per year is low very few range of animals live there



The photo of Afyon

Denizli Acıgöl

- Its attitude is 836m.
- The concentration of sodium potassium and sulfur very much so there are many species live
- Its total area is 41.34km².



The photo of Denizli Acıgöl

Denizli Tavas

- Its total area is 65.87km²
- Its attitude is 814m
- Compared to Acıgöl there are few species live



The photo of Denizli Tavas

Kale Akçay

- Its total area is 0.20 km
- Its attitude is 1250 m.
- Only a few fishes and some plants live there
- The taste of its water is sweet.



The photo of Kale Akçay

APPENDIX II

Calculations for other lakes and rivers

Calculation for Menderes

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.71

0.5M: After adding HNO₃: 1.82

$$\frac{7.71 - 1.82}{7.52} \times 100 = 70.9 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.44 \%$$

$$79.8 \pm 0.44 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.14 \%$$

$$82.5 \pm 0.14\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.41 \%$$

$$74.8 \pm 0.41\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Menderes river (in 0.5 HNO₃)

$$\frac{0.44 + 0.14 + 1.03 + 0.41 + 0.92}{5} = \pm 0.51$$

So for 1M HNO₃ The average ph change in Menderes river is = 72.7 ± 0.51

Error Calculations

For 0.5M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 3.69 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.17 \%$$

Trail 3

$$\frac{|77.7 - 71.1|}{77.7} \times 100 = 7.61 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 6.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.61 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.78}{6.73} \times 100 = 73.0 \%$$

0.2M: Before adding HNO₃: 6.79

0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$777.8 \pm 0.44 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Menderes river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Menderes river is = 76.7 ± 0.78

Error Calculations

For 0.2M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.28 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.85 \%$$

For 0.1M concentration

0.1M: After adding HNO₃: 6.72

0.1M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.1 M: Before adding HNO₃: 7.51

0.1M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.1M: Before adding HNO₃: 6.79

0.1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 79.8 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Menderes river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.49$$

So for 1M HNO₃ The average ph change in Menderes river is = 71.7 ± 0.58

Error Calculations

For 0.1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 8.75 \%$$

For 0.05M concentration

0.05M: Before adding HNO₃: 6.72

0.05M: After adding HNO₃: 1.32

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.05 M: Before adding HNO₃: 7.51

0.05M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.05M: Before adding HNO₃: 6.79

0.05M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.49 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.83\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.82 \%$$

Average uncertainty for Menderes river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Menderes river is = 76.9 ± 0.88

Error Calculations

For 0.05M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

Calculations for Kale

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

1M: Before adding HNO₃: 6.79

1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

1M: Before adding HNO₃: 6.73

1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.42 \%$$

$$79.8 \pm 0.42 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.17 \%$$

$$82.5 \pm 0.17\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Kale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.44 + 0.92}{5} = \pm 0.57$$

So for 1M HNO₃ The average ph change in Kale river is = 76.7 ± 0.57
Error Calculations

Error Calculations

For 1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.51

0.5M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Kale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.46$$

So for 1M HNO₃ The average ph change in Kale river is = 67.7 ± 0.59

Error Calculations

For 0.5M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.2M: Before adding HNO₃: 6.79

0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Kale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.38$$

So for 1M HNO₃ The average ph change in Kale river is = 76.7 ± 0.38

Error Calculations

For 0.2M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.1M concentration

0.1M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.1 M: Before adding HNO₃: 7.51

0.1M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.1M: Before adding HNO₃: 6.79

0.1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Kale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.79$$

So for 1M HNO₃ The average ph change in Kale river is = 71.1 ± 0.51

Error Calculations

For 0.1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.05M concentration

0.05M: Before adding HNO₃: 6.72

0.05M: After adding HNO₃: 1.32

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.05 M: Before adding HNO₃: 7.51

0.05M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.05M: Before adding HNO₃: 6.79

0.05M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Kae river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.47$$

So for 1M HNO₃ The average ph change in Kale river is = 70.5 ± 0.47

Error Calculations

For 0.05M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

Calculations for Pamukkale

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

1M: Before adding HNO₃: 6.79

1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

1M: Before adding HNO₃: 6.73

1M: After adding HNO_3 : 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Pamukkale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.98$$

So for 1M HNO₃ The average ph change in Pamukkale river is = 79.7 \pm 0.98

Error Calculations

For 1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

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% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.51

0.5M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Pamukkale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.23$$

So for 1M HNO₃ The average ph change in Pamukkale river is = 81.3 ± 0.23

Error Calculations

For 0.5M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.2M: Before adding HNO₃: 6.79

0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Pamukkale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.56$$

So for 1M HNO₃ The average ph change in Pamukkale river is = 86.7 ± 0.56

Error Calculations

For 0.2M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.1M concentration

0.1M: Before adding HNO₃: 6.72

0.1M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.1 M: Before adding HNO₃: 7.51

0.1M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.1M: Before adding HNO₃: 6.79

0.1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Pamukkale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Pamukkale river is = 77.7 ± 0.58

Error Calculations

For 0.1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.05M concentration

0.05M: Before adding HNO₃: 6.72

0.05M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.05 M: Before adding HNO₃: 7.51

0.05M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.05M: Before adding HNO₃: 6.79

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0.05M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 78.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92\%$$

Average uncertainty for Pamukkale river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Pamukkale river is = 77.7 ± 0.58

Error Calculations

For 0.05M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6\%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18\%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21\%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76\%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

Calculations for Temelli

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

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1M: Before adding HNO_3 : 6.79

1M: After adding HNO_3 : 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

1M: Before adding HNO_3 : 6.73

1M: After adding HNO_3 : 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92\%$$

Average uncertainty for Temelli river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Temelli river is = 77.7 ± 0.58

Error Calculations

For 1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6\%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18\%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21\%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76\%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.51

0.5M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

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0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92\%$$

Average uncertainty for Temelli river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Temelli river is = 77.7 ± 0.58

Error Calculations

For 0.5M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6\%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18\%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21\%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.2M: Before adding HNO₃: 6.79

0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.43\%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Temelli river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Temelli river is = 77.7 ± 0.58

Error Calculations

For 0.2M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.1M concentration

0.1M: Before adding HNO₃: 6.72

0.1M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.1 M: Before adding HNO₃: 7.51

0.1M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.1M: Before adding HNO₃: 6.79

0.1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.1M: Before adding HNO₃: 6.73

0.1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

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$$82.5 \pm 0.16\%$$

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Trail 4

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$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

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0.05M: Before adding HNO₃: 6.72

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$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

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0.05M: After adding HNO₃: 1.82

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0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 72.0 \%$$

0.05M: Before adding HNO₃: 6.79

0.05M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 73.5 \%$$

0.05M: Before adding HNO₃: 6.73

0.05M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 78.8 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

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% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

Calculations for Afyon

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

1M: Before adding HNO₃: 6.79

1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

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$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

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$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

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For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

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0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

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0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

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Calculations for Denizli Acıgöl

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

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$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

Demirağ Oğun
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0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.51

0.5M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Afyon river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Afyon river is = 77.7 ± 0.58

Error Calculations

For 0.5M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

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$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

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0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

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Trail 1:

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$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Afyon river is = 73.7 ± 0.78

Error Calculations

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$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

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Calculations for Denizli Tavas

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5 \%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

1M: Before adding HNO₃: 6.79

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% Error =

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For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

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0.2 M: Before adding HNO₃: 7.51

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For 0.05M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

Calculations for Akçay kale

For 1M concentration

1M: Before adding HNO₃: 7.69

1M: After adding HNO₃: 2.36

$$\frac{7.69 - 2.36}{7.69} \times 100 = 69.3 \%$$

1 M: Before adding HNO₃: 7.68

1M: After adding HNO₃: 2.36

$$\frac{7.68 - 2.36}{7.68} \times 100 = 69.5\%$$

1M: Before adding HNO₃: 7.72

1M: After adding HNO₃: 1.88

$$\frac{7.72 - 1.88}{7.72} \times 100 = 73.0 \%$$

1M: Before adding HNO₃: 6.79

1M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

1M: Before adding HNO₃: 6.73

1M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

$$6.79 - 1.37 = 5.42 \pm 0.02$$

$$\frac{0.02}{5.42} \times 100 = 0.40 \%$$

$$79.8 \pm 0.40 \%$$

Trail 2 :

$$7.53 - 1.32 = 6.21 \pm 0.01$$

$$\frac{0.01}{6.21} \times 100 = 0.16 \%$$

$$82.5 \pm 0.16\%$$

Trail 3

$$6.73 - 1.88 = 4.85 \pm 0.05$$

$$\frac{0.05}{4.85} \times 100 = 1.03 \%$$

$$72.1 \pm 1.03\%$$

Trail 4

$$6.65 - 1.73 = 4.92 \pm 0.02$$

$$\frac{0.02}{4.92} \times 100 = 0.4 \%$$

$$74.8 \pm 0.43\%$$

Trail 5

$$6.82 - 1.37 = 5.45 \pm 0.05$$

$$\frac{0.05}{5.45} \times 100 = 0.92\%$$

$$79.8 \pm 0.92 \%$$

Average uncertainty for Akçay river (in 1M HNO₃)

$$\frac{0.40 + 0.16 + 1.03 + 0.43 + 0.92}{5} = \pm 0.58$$

So for 1M HNO₃ The average ph change in Akçay s river is = 77.7 ± 0.58

Error Calculations

For 1M HNO₃ solution :

Trail 1

$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

Trail 2

$$\frac{|77.7 - 82.5|}{77.7} \times 100 = 6.18 \%$$

Trail 3

$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.5M concentration

0.5M: Before adding HNO₃: 6.72

0.5M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.5 M: Before adding HNO₃: 7.51

0.5M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.5M: Before adding HNO₃: 6.79

0.5M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.5M: Before adding HNO₃: 6.73

0.5M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

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So for 1M HNO₃ The average ph change in Akçay s river is = 77.7 ± 0.58

Error Calculations

For 0.5M HNO₃ solution :

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$$\frac{|77.7 - 79.8|}{77.7} \times 100 = 27.6 \%$$

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$$\frac{|77.7 - 72.1|}{77.7} \times 100 = 7.21 \%$$

Trail 4

$$\frac{|77.7 - 74.0|}{77.7} \times 100 = 4.76 \%$$

Trail 5

$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.2M concentration

0.2M: Before adding HNO₃: 6.72

0.2M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.2 M: Before adding HNO₃: 7.51

0.2M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.88

$$\frac{6.73 - 1.88}{6.73} \times 100 = 73.0 \%$$

0.2M: Before adding HNO₃: 6.79

0.2M: After adding HNO₃: 1.82

$$\frac{6.791 - 1.82}{6.79} \times 100 = 77.8 \%$$

0.2M: Before adding HNO₃: 6.73

0.2M: After adding HNO₃: 1.42

$$\frac{6.73 - 1.42}{6.73} \times 100 = 75.5 \%$$

Uncertainty Calculations

Trail 1:

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$$\frac{|77.7 - 79.9|}{77.7} \times 100 = 2.83 \%$$

% Error =

$$\frac{|27.3 + 6.18 + 7.20 + 4.76 + 2.83|}{5} \times 100 = 9.65 \%$$

For 0.1M concentration

0.1M: Before adding HNO₃: 6.72

0.1M: After adding HNO₃: 1.32

$$\frac{6.72 - 1.32}{6.79} \times 100 = 74.4 \%$$

0.1 M: Before adding HNO₃: 7.51

0.1M: After adding HNO₃: 1.82

$$\frac{7.51 - 1.82}{7.52} \times 100 = 70.6 \%$$

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APPENDIX III

My pictures while measuring the pH of solutions



Picture 1: Measuring pH with Vernier



Picture 2: Measuring pH with Vernier



Picture 3: Picture of solutions